Journal of Clinical Neuroscience 21 (2014) 1116–1122

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical Study

Delayed complications after flow-diverter stenting: Reactive in-stent stenosis and creeping stents

José E. Cohen [a,b,*], John Moshe Gomori [b], Samuel Moscovici [a], Ronen R. Leker [c], Eyal Itshayek [a]

[a] Department of Neurosurgery, Hadassah–Hebrew University Medical Center, POB 12000, Jerusalem 91120, Israel
[b] Department of Radiology, Hadassah–Hebrew University Medical Center, Jerusalem, Israel
[c] Department of Neurology, Hadassah–Hebrew University Medical Center, Jerusalem, Israel

ARTICLE INFO

Article history:
Received 24 November 2013
Accepted 29 November 2013

Keywords:
Brain aneurysm
Complications
Flow-diverter stent
In-stent stenosis
Stent migration

ABSTRACT

We assessed the frequency and severity of changes in stent configuration and location after the treatment of intracranial aneurysms, and patterns of in-stent stenosis. We retrospectively reviewed data for consecutive aneurysm patients managed with endovascular implantation of flow-diverter stents (Silk Flow Diverter [Balt Extrusion, Montmorency, France] and Pipeline Embolization Device [ev3/Coviden, Minneapolis, MN, USA]) from October 2011 to July 2012. Routine 2, 6, 9–12, and 16–20 month follow-up angiograms were compared, with a focus on changes in stent configuration and location from immediately after deployment to angiographic follow-up, and the incidence and development of in-stent stenosis. Thirty-four patients with 42 aneurysms met inclusion criteria. The Silk device was implanted in 16 patients (47%, single device in 15), the Pipeline device in 18 (53%, single device in 16). On first follow-up angiography, in-stent stenosis was observed in 38% of Silk devices and 39% of Pipeline devices. In-stent stenosis was asymptomatic in 12 of 13 patients. One woman presented with transient ischemic attacks and required stent angioplasty due to end tapering and mild, diffuse in-stent stenosis. Configuration and location changes, including stent creeping and end tapering were seen in 2/16 patients (13%) with Silk devices, and 0/18 patients with Pipeline devices. We describe stent creeping and end tapering as unusual findings with the potential for delayed clinical complications. In-stent stenosis, with a unique behavior, is a frequent angiographic finding observed after flow-diverter stent implant. The stenosis is usually asymptomatic; however, close clinical and angiographic monitoring is mandatory for individualized management.

1. Introduction

Delayed complications associated with implantation of flow-diverter stents have not been completely understood or well characterized. They have generally been classified as either ischemic or hemorrhagic events, and grossly subdivided based on timing and the suspected underlying mechanism [1,2]. In general, procedural complications can be usually be explained by technical and, secondarily, by hemodynamic factors. Delayed complications require consideration of more complex and less well understood biological factors. We assessed the frequency and severity of changes in stent configuration and location as well as the nature and severity of in-stent stenosis at routine angiographic follow-up in patients who underwent implantation of flow-diverter stents for the management of intracranial aneurysms. We discuss the clinical implications and management of these findings.

2. Methods

2.1. Patients

We retrospectively reviewed our Medical Center's digital record system to identify all (consecutive) patients who underwent endovascular procedures involving implantation of flow-diverter stents for the management of intracranial internal carotid artery (ICA) aneurysms with a diameter <25 mm from October 2011 to July 2012. Patients treated before this period were excluded from the study to reduce influence of the learning curve effect on final results.

Clinical information was retrospectively retrieved from the digital patient record system. Procedural angiograms were analyzed and findings compared from routine 2, 6, 9–12, and 16–20 month angiographic follow-up. Image analysis was performed by two experienced neuro-interventionalists in consensus (J.E.C., J.M.G.). We specifically sought to evaluate changes between the original stent configuration and location from immediately after

* Corresponding author. Tel.: +972 2 677 7092; fax: +972 2 641 6281.
E-mail address: jcohenns@yahoo.com (J.E. Cohen).

http://dx.doi.org/10.1016/j.jocn.2013.11.010
0967-5868/

deployment with the configuration and location on angiographic follow-up. Changes in stent configuration and location included delayed end tapering; configuration changes; signs of minor creeping (reorganization of the stent after implant, shown as a change in marker disposition) or major creeping (changes in the final position of the stent ends compared to original placement); or even migration.

We also evaluated the incidence, degree, and pattern of in-stent stenosis, defined as any growth process beyond the strict limits of the metallic mesh. In-stent stenosis was characterized as focal, multifocal, segmental, or diffuse. Stenosis was graded as mild, moderate, or severe based on in-stent stenosis of less than 25%, 25–50%, or more than 50%, respectively. Findings for each of the stent types used in the procedures were compared.

Patients with unusual or unexpected clinical or angiographic findings were reviewed for neuroradiological examination and additional non-routine angiograms if findings at routine follow-up or clinical presentation justified the unplanned procedure.

The study was performed according to guidelines from the Helsinki Agreement.

2.2. Medication and treatment

2.2.1. Anticoagulation

Elective patients were premedicated with clopidogrel 75 mg daily, as well as a single dose of aspirin 300 mg and then aspirin 100 mg daily starting 5 days before the procedure. Patients who required more urgent intervention, including those treated during a period of acute subarachnoid hemorrhage, were premedicated with a loading dose of 300–600 mg of clopidogrel, followed by 75 mg daily. Thrombocyte inhibition levels were confirmed using the VerifyNow P12Y12 assay (Accumetrics, San Diego, CA, USA) and a standard thrombocyte aggregation test. Patients were treated only if their thrombocyte inhibition level was above 40%. If the response was lower, additional loading doses or increased daily doses were administered until this criterion for intervention was achieved. If clopidogrel resistance was detected, clopidogrel was discontinued and ticlopidine was administered with a dose of 600 mg twice daily.

During every stent implant procedure, all patients received intravenous heparin to maintain an activated clotting time of 250–270 seconds. Heparinization was not reversed at the conclusion of the procedure.

A clopidogrel regimen of 75 mg daily or ticlopidine at 600 mg twice daily, in addition to aspirin at 100 mg per day, was maintained for 6 to 18 months based on angiographic and clinical findings; clopidogrel (or ticlopidine) was then discontinued, while aspirin was continued indefinitely.

2.2.2. Endovascular procedure

All procedures were performed by a senior interventional neurosurgeon (J.E.C.) and neuroradiologist (J.M.G.), both with over 10 years of experience in stent-placement techniques. All treatments were performed with the patient under general anesthesia using biplane angiographic guidance. Three-dimensional rotational angiography was performed for all patients, and working projections were determined. Parent artery measurements were obtained using three-dimensional reconstructions and two-dimensional working projections, with reference to microcatheter/guiding catheter size and external markers.

In all patients, a 6 French introducer sheath (Super Arrow-Flex Percutaneous Sheath Introducer Set, Teleflex, Limerick, PA, USA) was placed proximally in the parent artery, and then a 6 French guiding catheter (Envoy, Cordis Neurovascular, Miami Lakes, FL, USA; or Fargo or Fargomax, Balt Extrusion, Montmorency, France) was placed in the internal carotid or vertebral artery as distal as

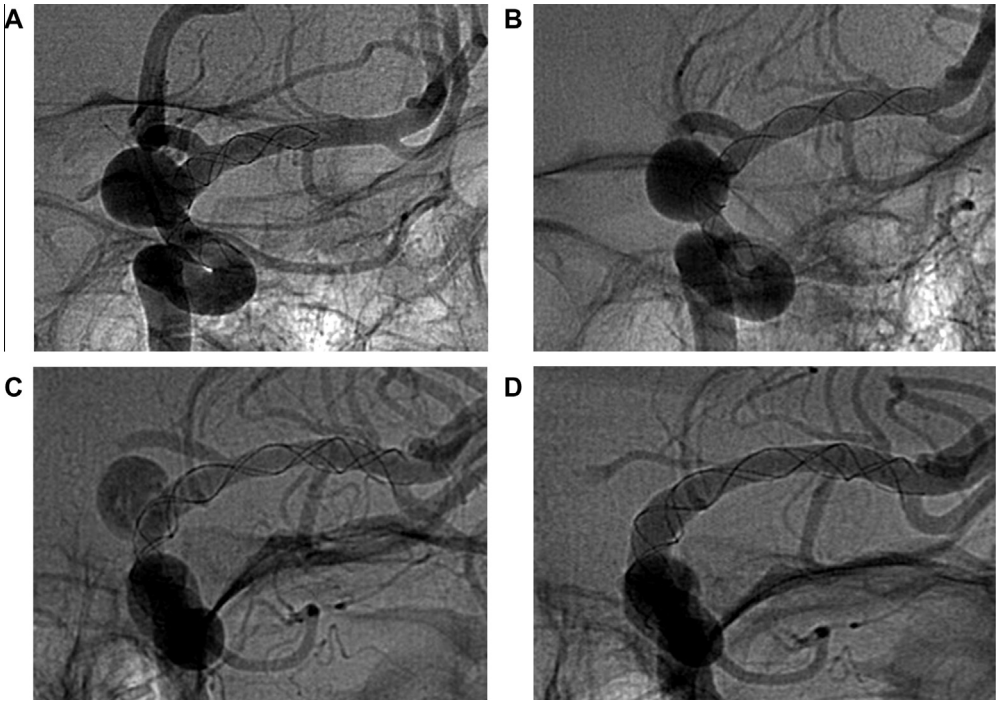

Fig. 1. Stent creeping seen in an 11-year-old girl who presented with an asymptomatic large left carotid ophthalmic aneurysm. (A) Unsubtracted selective left internal carotid artery angiogram shows a single Silk stent (Balt Extrusion, Montmorency, France) implanted across the aneurysm neck. Note that the distal end of the stent is at the level of the origin of an early temporal branch arising from M1 segment. (B) Follow-up angiogram obtained after 1.5 months showed distal "creeping" of the implanted stent (major creeping). Note the distal end of the stent reaching the middle cerebral artery bifurcation. The aneurysm is patent. (C) Follow-up angiogram obtained 3 months post-procedure shows stable position of the distal end of the stent compared to (B), but subtle changes in the stent marker distribution are noted (minor creeping). The aneurysm is still patent. (D) Follow-up angiogram obtained 12 months after stent implant shows stable configuration and position of the device with complete occlusion of the aneurysm.